1MP

NASA TECHNICAL TRANSLATION NASA TT F-15,424

AIRCRAFT OF THE FUTURE

I. Tolztych

(NASA-TT-F-15424) AIRCRAFT OF THE FUTURE (Techtran Corp.) 10 p HC $4.00 CSCL 01C

N74-19669

Unclas

G3/02 34378

Translation of "Flugzeuge der Zukunft," Technisch-Oekonomische Informationen der Zivilen Luftfahrt, Volume 8, No. 9, 1972 pp. 419-424, (A73-23682).

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D. C. 20546 APRIL 1974

STANDARD TITLE PAGE

1. Report No. NASA TT F-15,424	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle AIRCRAFT OF THE FUTURE		5. Report Date APRIL 1974
		6. Performing Organization Code
7. Author(s) I. Tolztych		8. Performing Organization Report No.
		10. Work Unit No.
9. Performing Organization Name and Address Techtran Corporation P.O. Box 729, Glen Burnie, Md. 21061		11. Contract or Grant No. NASw-2485
		13. Type of Report and Period Covered Translation
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, D. C. 20546		14. Sponsoring Agency Code

15. Supplementary Notes

Translation of "Flugzeuge der Zukunft," Technisch-Oekonomische Informationen der Zivilen Luftfahrt, Volume 8, No. 9, 1972, pp. 419-424, (A73-23682).

16. Abstract

Evaluation of the technical and economic efficiency of the types of aircraft likely to be developed in the coming decades involves discussion of the problem of evaluating the degree of structural maturity and perfection of passenger aircraft and their economic efficiency. Problems connected with the development of increasingly high-speed subsonic aircraft, supersonic, and, ultimately, hypersonic aircraft are discussed, including engine designs, fuels, and noise reduction. In addition, the use of VSTOLs to provide more efficient transportation between airports and city centers is considered.

17. Key Words (Selected by Author(s))		18. Distribution Statement Unclassified-Unlimited	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 8	22. Price

AIRCRAFT OF THE FUTURE

I. Tolztych

The development of civil aviation in the USSR has been governed by the needs of the national economy and the requirements of the population for operational efficiency of aviation. These requirements also form the basis for the planned development of new types of commercial aircraft, governing both the scope and volume of manufacture, flight technical data and efficiency. /419*

In countries which have their own aircraft industries, there are quite specific tendencies and trends in the development of commercial aircraft for service on fixed routes. In the United States, for example, these tendencies are characterized in particular by the existence of a great many small and large manufacturers, a vast expanse of continental and intercontinental routes, and other factors which are characteristic of the transportation system of that country. European countries mainly show a preference for short and medium-range aircraft.

According to data from the ICAO, the average annual increase in passenger traffic is approximately 12 to 15%. This fact is naturally unavoidably linked to the increase in the seating capacity of commercial aircraft, an increase in the air speed by 5 to 10%, still in the subsonic range, the replacement and retirement of turboprop aircraft by improved planes with jet engines, and reduction of the length of the runways through the use of short-range commercial aircraft, for the purpose of operating them from a far larger number of airports.

Operating conditions play an ever increasing role in the development of commercial aircraft. The number of convertible aircraft, in other words, planes which can be used either for passenger or freight service, and can therefore be modified into passenger and freight configurations, is growing. Another tendency is the appearance of VSTOL's and aircraft with STOL characteristics for use in shuttle service between airports and downtown. In the immediate future, supersonic transports will be entering regular service. Flight time will be reduced

*Numbers in the margin indicate pagination in the foreign text.

approximately 3 hours by these aircraft in traveling distances of approximately 6500 km. This is a significant increase in the productivity of the operating efficiency and is particularly significant on long-range flights. During the latter years of this century, it is expected that hypersonic transports will be in service, capable of traveling distances on the order of 10,000 to 15,000 km in 1.5 to 2.5 hours.

For purposes of evaluating present and future means of transport in aviation and their future, a method has been proposed which will make it possible to determine the degree of structural completeness and perfection and the economic efficiency of commercial aircraft as a function of concrete operating conditions.

It is quite clear even to the general public that the future belongs to aircraft which operate reliably, provide a comfortable ride, high air speed, and (equally important) operate economically and efficiently and can be introduced smoothly. Economic evaluation therefore boils down to a determination of the degree of the relative hourly productivity of an aircraft in the desired cruising range, the costs involved in conjunction with achieving the necessary /420
technical perfection of the aircraft, and the maintenance and servicing of the aircraft at airports. The net cost per ton-kilometer is used as a measure of economy. It is calculated from the ratio of the relative net cost per flight hour of the commercial aircraft in question and the relative hourly productivity. However, since both of these parameters generally depend upon the technical characteristics of the aircraft, the structural perfection of the aircraft and its flight-technical data are of critical significance.

The integral expression for the average of the net cost of a ton-kilometer is used as a criterion for evaluating technical-economic efficiency in a quite specific cruising range. Hence, this is a parameter which is suitable for all categories of commercial aircraft in accordance with their application. This criterion can also be used for determining the future applications of commercial aircraft.

The relative net cost per flight hour is calculated in the case in question under the same production and operating conditions, i.e., they are assumed or comparative values. The value of the relative hourly productivity used for the case in question for purposes of technical characterization is the hourly productivity of the aircraft, based on the unit of takeoff weight. The criterion for the structural and technical perfection of the commercial aircraft is the integral expression for the average value of the relative hourly productivity of the aircraft in a quite specific range. The value of this criterion is calculated using an equation which incorporates all of the various interrelated values of parameters and flight-technical data: cruising speed, aerodynamic efficiency, specific fuel consumption, payload factor, etc. Technical perfection is therefore expressed in the unit of ton-kilometers per hour and tons of takeoff weight.

The economic efficiency, like the technical perfection of a commercial aircraft, varies as a function of the development of aviation science and aviation technology; in this connection, the technical-economic level of development of commercial aircraft can be followed and derived over a period of years. Thus, for example, the level of technical perfection of various types of commercial aircraft has increased by about one and one-half times from 1960 to 1970.

The faster rate of development of technical-economic efficiency of commercial aircraft, the increase in passenger traffic (which is almost three times the rate of population growth) make it necessary to increase the productivity of subsonic aircraft by increasing their takeoff weights and their seating capacities, since their air speeds have already reached the maximum possible value of approximately 1,000 km/h. We are now faced with the question of whether the problem with which we are dealing can be solved by increasing the number of aircraft. Clearly, it cannot.

A smaller number of jumbo jets makes the problems of flight safety easier and reduces the scope of the maintenance and service work at airports. Thanks to improved aerodynamic configuration, higher payload factor and total useful load factor as well as smaller specific masses for equipment, the net costs of jumbo jets are lower.

As the takeoff weight continues to rise, for example to levels of 500 tons or more, problems of ensuring efficiency of **aircraft control** due to the sharp increase in the inertial moment will be bound to arise. The need for very large commercial aircraft carrying 1,000 passengers or more, whose manufacture is quite feasible from the technical standpoint, will depend upon a further increase in passenger traffic assuming an increase in the intensity of flight operations, a further improvement in shuttle service between the airport and downtown, and a number of other factors involved in the development of aviation. /421

It is assumed that most of the operational efficiency will be ensured during the next 15 to 20 years using subsonic aircraft. Their aerodynamic qualities will continue to increase. The specific fuel consumption will drop. As a result, we can assume a further decrease in the net cost per ton-kilometer of 15 to 20%.

In the next decade, these tendencies will result in a concentration on the development of medium-range commercial aircraft, designed for 350 to 500 passengers, with a cruising speed of 900 to 950 km/hr; the takeoff weights of several types will reach 350 tons. With maximum payloads of 30 to 60 tons, it will be possible to operate such aircraft on runways 2,500 to 5,500 km long. They will then be equipped as a rule with 3 or 4 dual cycle engines with maximum thrusts up to 24 Mp (modern engines developed thrusts of approximately 10 Mp).

A significant obstacle to the development of the operational efficiency of aviation is the link between the airport and downtown. Hence, it will be necessary to develop VSTOL's with high speed, which can be operated from relatively small pads located in the heart of downtown (Figure 1). The main problem in this connection is noise reduction in the vicinity of the airport. Flight tests of various types of such aircraft with turboprop and jet engines are currently in progress. The jet aircraft of this type are designed for 80 to 100 passengers, an air speed of 800 km/hr and a maximum range (with reduced payload) of up to 800 km. It is anticipated that such craft will be operative until 1980. VTOL's with turboprop engines have been in the stage of prototype testing for some time now, without sufficient positive results having been obtained as yet.

The further increase in technical-economic efficiency of subsonic commercial aircraft is dependent to a large extent on the area of aerodynamics (increasing the aerodynamic efficiency during takeoff and cruising, and improving the lifting force of the wings on takeoff by modifying the boundary layer). Other important aspects are the development of engines (reduction of specific fuel consumption, relative weight of propulsion units, introduction of modular construction, and so on), airframe construction (reduction of the airframe mass component of the takeoff weight from 25 to 20%, use of solid solutions which provide the strength of steel at the specific gravity of aluminum, use of adhesives, use of heat-resistant alloys) and the area of equipment (automation of the operation of the fuel system and other systems, miniaturization, increasing the reliability and reducing the weight).

A flight covering a distance of 9,000 to 10,000 km aboard a number of intercontinental long--range aircraft requires approximately 12 hours today. After 4 hours in flight, both the crew and the passengers are fatigued. The operational efficiency on continental and intercontinental routes is increasing, however. By virtue of the circumstances discussed here, we can say with complete confidence that the productivity of a commercial aircraft on such routes will be improved not only by increasing the takeoff weight and useful load but also to a large extent by raising the speed. /422

Increasing the cruising speed of a supersonic transport to 5,000 km/h and a hypersonic aircraft to 6,000 km/hr or more will have a significant influence on the productivity of the aircraft (Figures 2 and 3).

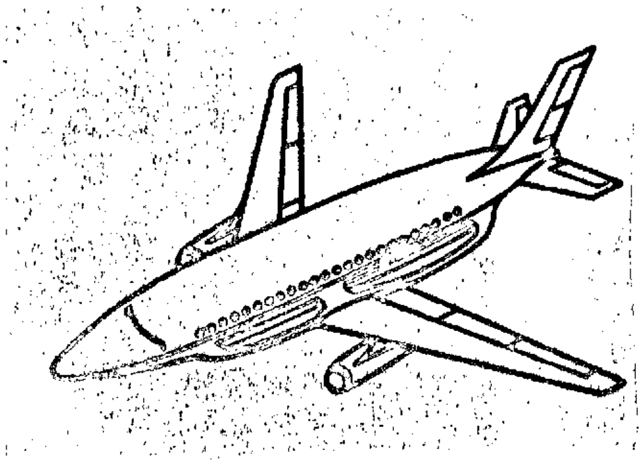

Figure 1. Sketch of a VTOL Aircraft (France).

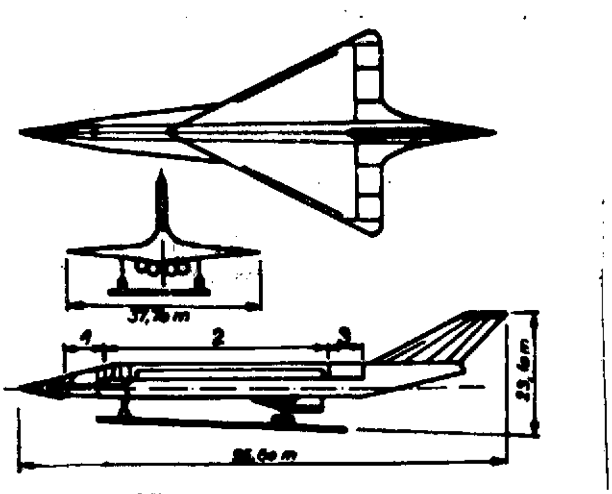

Figure 2. Proposed Design of a Hypersonic Commercial Aircraft with a Delta Wing and Tanks for Liquid Hydrogen. 1, Cockpit; 2, Cabin for 200 Passengers; 3, Baggage Area.

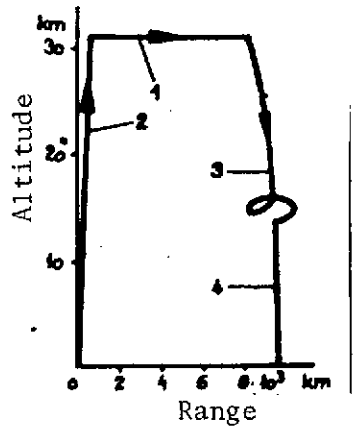

Figure 3. Flight Profile of a Hypersonic Commercial Aircraft. 1, Cruising (M = 6; 1 h 7 min); 2, Climb (18 min); 3, Descent (20 min); 4, Holding pattern M = 0.9 and landing (30 min).

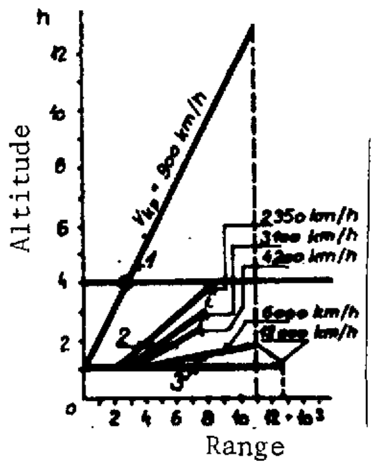

Figure 4. Flight Time Versus Distance for Various Commercial Aircraft. 1, Subsonic flight, V_B = 900 km/hr; 2, Supersonic flight, V_B = 2,350 km/hr, 3,100 km/hr, 4,200 km/h; 3, Hypersonic flight, V_B = 6,000 km/h, 12,000 km/h.

Moreover, there will be a clear saving of company and personnel time, something which is of tremendous economic significance under the conditions existing in our country.

Figure 4 shows the flying time for flights over various distances with a commercial load of no less than 6 to 8% of the takeoff weight as a function of the air speed.

Flight at supersonic and hypersonic speeds depends upon the solution of a number of problems which have to do with reducing the aerodynamic efficiency, a significant aerodynamic heating of the /423
surface of the transport, and an increase in specific fuel consumption by the engines. These problems will also be caused by the rise in the manufacturing costs of these aircraft, the degree of complexity of the design (marked by the use of titanium and other alloys), as well as the use of efficient cooling systems and new automatic control mechanisms. Transport planes of this kind require special types of combination power plants. Hydrocarbon fuels such as kerosene can no longer be used at air speeds of about 4,000 km/hr. In all probability, such engines will be powered by cryogenic fuels.

Increasing the air speed to approximately 2,500 km/hr will allow the use of the well-developed airframe construction made of aluminum alloys, since most of the surface will be exposed to temperatures up to 100°C.

The operating costs for a supersonic transport (SST) will be compensated by the increasing hourly productivity, which, like the operating costs, will increase by approximately two and one-half times. As the air speeds of the supersonic aircraft continue to increase, the hourly productivity will rise to a lesser degree, but operating costs will continue to rise, since the airframe construction using titanium and steel will be employed and new cooling systems and the like will be installed. The weight of the hydrocarbon fuel of a SST will amount to 50% of the takeoff weight for flights over long distances.

Increasing the air speed of a SST with engines burning hydrocarbon fuel (kerosene) to 4,000 to 5,000 km/hr would be economically unfeasible. It would be preferable to develop and design an SST which would operate at an air speed of approximately 2,500 km/hr, since the net cost of a ton-kilometer would be on the order of magnitude of that of a subsonic aircraft, and the flight time for a given distance would be cut by more than half. The range of SST's is between 2,500 and 6,500 km; this assumes a takeoff weight of 170 to 200 tons. The runway length required for SST's is approximately 3,000 m. The possible improvement that could be made in future in the aerodynamic efficiency of the SST and the reduction of the specific fuel consumption by its engines would lead to an increase in range by 1,500 to 2,000 km.

With a further increase in air speed to 6,000 km/h or more, the aerodynamic efficiency while cruising, in comparison with subsonic craft, would be cut by a factor of 3 and at air speeds of 12,000 km/hr by a factor of 4. Methane and liquid hydrogen are more or less suitable as fuels for these hypersonic aircraft, since they can be used at the same time as a coolant or as coolants in the cooling system. This means that new types of engines will be required. In all probability, they will be ram jet engines with supersonic combustion. The use of combination power plants — pairing a jet engine with a ram jet engine — is unavoidable. The jet engine will operate during takeoff and landing, while the ram jet will be used while cruising. The flight altitude at a speed of 5,000 km/hr will be 25,000 m.

Despite a number of unsolved problems, civilian transports operating at hypersonic speed show promise both with respect to their technical and economic parameters. The technical perfection of a hypersonic aircraft, in accordance with the methods described here and with use of the derived criterion, will /424 increase 3 to 6 times in comparison with subsonic aircraft, assuming air speeds of 6,000 km/hr and 12,000 km/hr, respectively.

The economic efficiency of the hypersonic aircraft, calculated by the average value of the integral expression of the net cost per ton-kilometer over a specific cruising range interval, is largely dependent upon the price of fuel, i.e., the cost of liquid hydrogen. If we assume that liquid hydrogen is 3 times as expensive as kerosene for a given volume, the net cost per ton-kilometer at speeds of 6,000 to 12,000 km/hr will be 150 to 130% higher than the net cost for a subsonic aircraft.

Hypersonic aircraft can be operated out of airports with runway lengths of 3,000 to 3,500 m. With cruising ranges of 11,000 to 12,000 km, we will have to deal with takeoff weights of 250 to 350 tons. Flight altitude will be approximately 40,000 m. The distances covered in climbing to these altitudes and descending from them will be approximately 600 km.

Hypersonic aircraft for passenger service will probably come into use during the next 15 to 20 years. Experimental testing is already underway. Prototypes of certain structural elements are being built. By the year 2000, hypersonic commercial aircraft carrying 400 to 500 passengers and having takeoff weights of 500 to 600 tons will be in use. Their fuselages will be 100 to 120 m long, and their diameters will be 7 to 8 m. They will be comfortable machines.

(Translated from: Grazhdanskaya Aviatsiya, No. 6, pp. 18-19, 1972.
Translator: Dr.-Ing. Klaus Apel)

Translated for the National Aeronautics and Space Administration under Contract No. NASw-2485 by Techtran Corporation, P. O. Box 729, Glen Burnie, Md. 21061.
Translator: W. J. Grimes, M.I.L.